CHAPTER 3

AFFECTED ENVIRONMENT FOR DOMESTIC PROGRAMMATIC ALTERNATIVES

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Chapter 3, the affected environment for the domestic programmatic alternatives, provides the context to understand the environmental impacts described in Chapter 4. The affected environment serves as a baseline from which environmental impacts caused by implementation of the domestic programmatic alternatives can be evaluated. The baseline conditions are the currently existing conditions.

This section describes the affected environment with respect to nuclear electric power generation, including nuclear power plants and related nuclear infrastructure and their effects on the resource areas of air quality, land use, water resources, socioeconomics, radiological waste management, and transportation. The region of interest is the entire United States because facilities associated with the programmatic alternatives could be deployed anywhere in the country. However, emphasis is placed on the contiguous 48 states because they represent the vast majority of population and land area and allow for more effective transportation of materials and wastes. There are no existing or proposed commercial nuclear power reactors in Alaska or Hawaii.

3.1 NUCLEAR POWER PLANTS AND INFRASTRUCTURE

Nuclear power facilities include both generation plants and the associated infrastructure necessary to provide fuel and dispose of wastes. The main structures at a nuclear power plant include the reactor facility, cooling systems, and waste storage facilities. The land where these structures are sited, as well as surrounding resources and communities, is considered part of the affected environment of the power plant. There are currently 104 commercial nuclear power reactors in operation at 65 sites in the United States (NRC 2007e).

Current U.S. nuclear infrastructure supports uranium mining and milling, uranium enrichment, fuel fabrication, and management of spent nuclear fuel (SNF). As with any commercial power plant, transmission line infrastructure for connection to the power grid is also required. These components of the nuclear infrastructure involve numerous sites and facilities, and like the generation plants, each has surrounding land, resources, and communities that constitute the affected environment. Brief descriptions of these components are provided below, and more details are found in Chapter 4, Section 4.1 (NRC 2007d).

Uranium is mined in the United States and numerous countries around the world, including Canada, Australia, and Kazakhstan (WNA 2008e). Three principal methods are used to mine uranium: surface (open pit), underground, and *in-situ* leaching (solution mining). The method of extraction is dependent on the grade, size, location, and geology of the deposit, and is generally selected to maximize ore recovery within economic constraints. A low-grade cutoff point is established on a site-specific basis and depends on recovery costs at the site, the market price of the ore, and feed requirements at the mill (IAEA 1998). According to the Energy Information Administration, there were 10 operating uranium mines in the United States in 2006 (5 underground mines and 5 *in-situ* leaching mines) (EIA 2007n).

Uranium ore deposits in the United States are generally rich in radium and vanadium. Radium has some commercial use, mainly in the medical industry, and vanadium is used as a hardener in the steel production industry. The isotopic content of uranium metal, as found naturally in ore deposits, is mostly uranium-238. Uranium-235 (U-235) generally represents around 0.72 percent of natural uranium ore, by weight. This percentage is far less than the 3 to 5 percent U-235 required by current U.S. nuclear power plants as fuel for electricity generation. Therefore, uranium must be enriched so it can be used in commercial nuclear power plants. Enrichment is the process applied to increase the percentage of the fissile U-235 isotope and decrease the percentage of U-238 (NRC 2007b).

Fuel fabrication is the final step in the process used to produce uranium fuel for commercial light water nuclear power reactors (NRC 2007c). During fabrication, enriched uranium hexafluoride (UF_6) is converted to uranium dioxide (UO_2) powder that is then ground, pressed, sintered (i.e., fused together), and loaded into prefabricated zirconium alloy clad tubes. The tubes are then filled with an inert gas and welded shut. These tubes, or pins, are bundled together and made into a fuel assembly (NRC 2007c).

Use of uranium as fuel in a reactor produces SNF. Management of SNF is required for the operation of nuclear power plants. SNF is stored by the nuclear power plants until an approved disposal facility is made available. The disposal of commercial SNF and U.S. Department of Energy (DOE) SNF and high-level waste (HLW) is planned for a geologic repository at Yucca Mountain in Nevada (DOE 2008g). SNF could be transported to the repository by rail or truck, or both. On April 8, 2004, DOE issued a Notice of a Record of Decision in the *Federal Register* (69 FR 18557), stating the preference to transport HLW and SNF to Yucca Mountain mainly by rail with a smaller portion of the SNF transported by truck. Also on April 8, 2004, DOE issued a Notice of Intent to Prepare an EIS for the Alignment, Construction, and Operation of a Rail Line for Shipments of SNF, HLW, and Other Materials from a Site Near Caliente, Lincoln County, Nevada, to a Geologic Repository at Yucca Mountain, Nye County, Nevada (69 FR 18565).

3.2 BASELINE ENVIRONMENTAL CONDITIONS OF THE NUCLEAR POWER INDUSTRY

The subsections below describe the nuclear power industry with respect to air quality, land use, water resources, socioeconomics, radiological waste management, and transportation.

3.2.1 Air Quality

In administering the *Clean Air Act*, the U.S. Environmental Protection Agency (EPA) has identified seven air pollutants that have well-known adverse effects on human health and welfare. These seven pollutants are called *criteria* pollutants, and they include carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), lead (Pb), particulate matter with a diameter of less than 10 micrometers (PM_{10}), and particulate matter with a diameter less than 2.5 micrometers ($PM_{2.5}$). The EPA has established National Ambient Air Quality Standards (NAAQS) that limit the concentration levels for these pollutants in the ambient air (40 *Code of Federal Regulations* [CFR] Part 50). Regulations also are established for other harmful pollutants, such as mercury, asbestos, radionuclides, and the 188 hazardous air pollutants (HAPs) listed at 40 CFR Part 61. However, the concentration levels in ambient air for these pollutants are generally not regulated; rather, these pollutants are regulated on the basis of emission rates. In addition, there are pollutants that are presently unregulated, such as certain greenhouse gases (e.g., carbon dioxide), that also may have harmful environmental effects.

Nitrogen and sulfur compounds can react with the air to form acid compounds. Precipitation such as rain or snow causes these compounds to fall to the earth (acid rain). Some pollutants react with the air and erode the ozone layer that blocks harmful radiation from the sun. Ozone layer reductions allow higher levels of B-type ultraviolet radiation (UVB) to reach the surface of the earth. Ozone reductions cause a variety of adverse conditions with respect to plant growth, marine ecosystems, and terrestrial and biogeochemical cycles, and have been linked to increased incidences of skin cancer in humans (EPA 2006e).

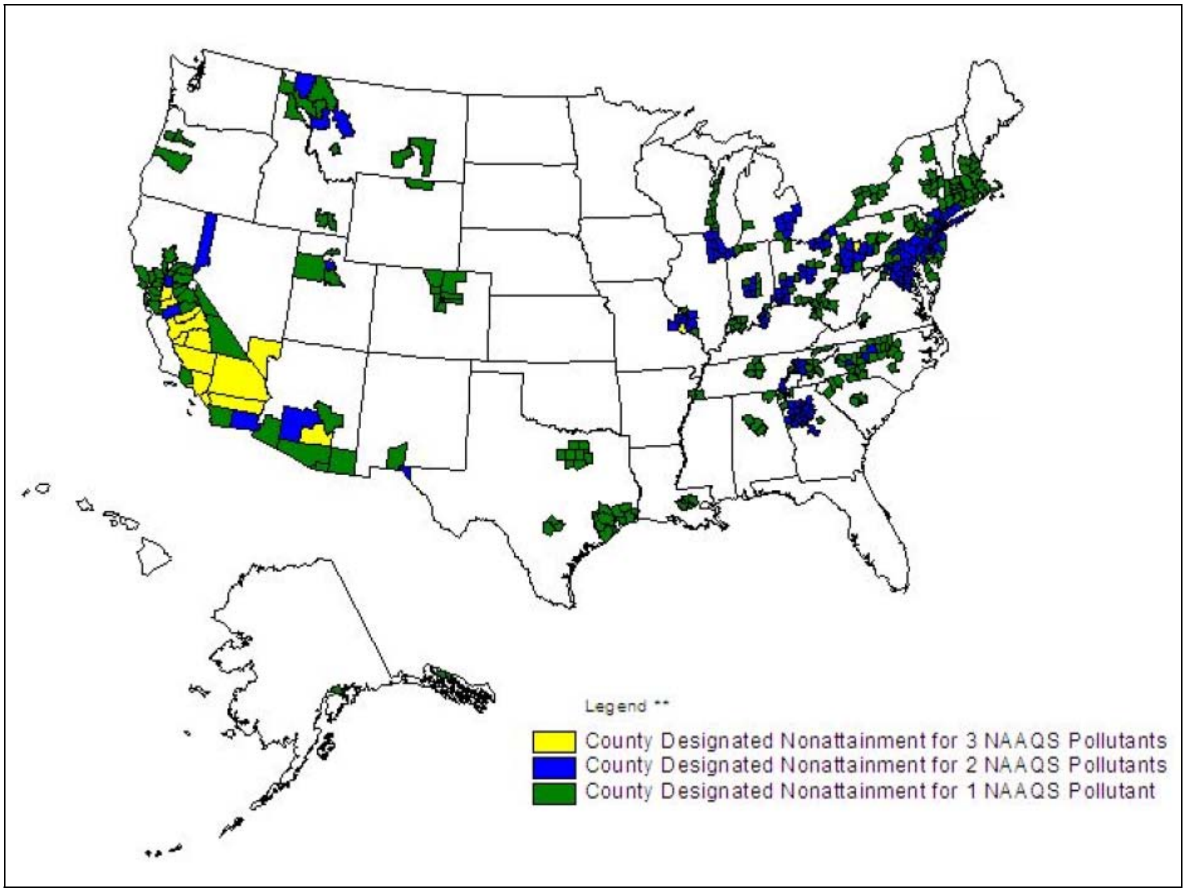
Regional air quality is primarily a function of pollutant emission levels in the area. For this reason, air quality is generally much lower in urban and highly industrialized areas where a large number of pollutant emission sources are present in a relatively small area. To a lesser extent, weather patterns, topography and vegetation cover, and state air quality standards can affect regional air quality. Regions of the United States that currently fail to satisfy the NAAQS (i.e., nonattainment regions) are illustrated in Figure 3.2.1-1 (EPA 2007b). A more detailed discussion of air quality concepts is provided in Chapter 9.

Nuclear power plants have a relatively low impact on air quality because they do not involve the chemical combustion of fossil fuels. Auxiliary equipment and processes are the principal direct sources of nonradiological emissions from a nuclear power plant. Other nonradiological emissions are generated by trains and trucks that transport materials to and from the plant, and from plant worker vehicles.

Activities and processes that support the nuclear power industry also generate nonradiological and/or radiological emissions. For example, emissions are produced by equipment and activities at the uranium mines where raw uranium ore is extracted, by processes applied to convert uranium ore into enriched reactor grade fuel, and by transportation systems that transfer material between destinations.

Underground uranium mines produce exhaust which typically includes radon-222 (Rn-222) in measurable concentrations. Rn-222 is present in the exhaust because it emanates from the ore. The concentration of Rn-222 in mine exhaust varies and depends on the ventilation rate, mine volume, mine age, grade of exposed ore, size of active work areas, moisture content and porosity of the rock, barometric pressure, and mining practices. "A previous EPA study indicates that higher Rn-222 emission rates occur at older mines, probably because there are larger surface areas of exposed ore and sub-ore" (EPA 1983).

Small levels of radiological emissions may be released at a nuclear power plant from routine operations; however, these emissions are continuously monitored and are subject to strict Federal regulations under the aegis of the U.S. Nuclear Regulatory Commission (NRC). Radiation dose exposures are small relative to doses from natural radioactivity.

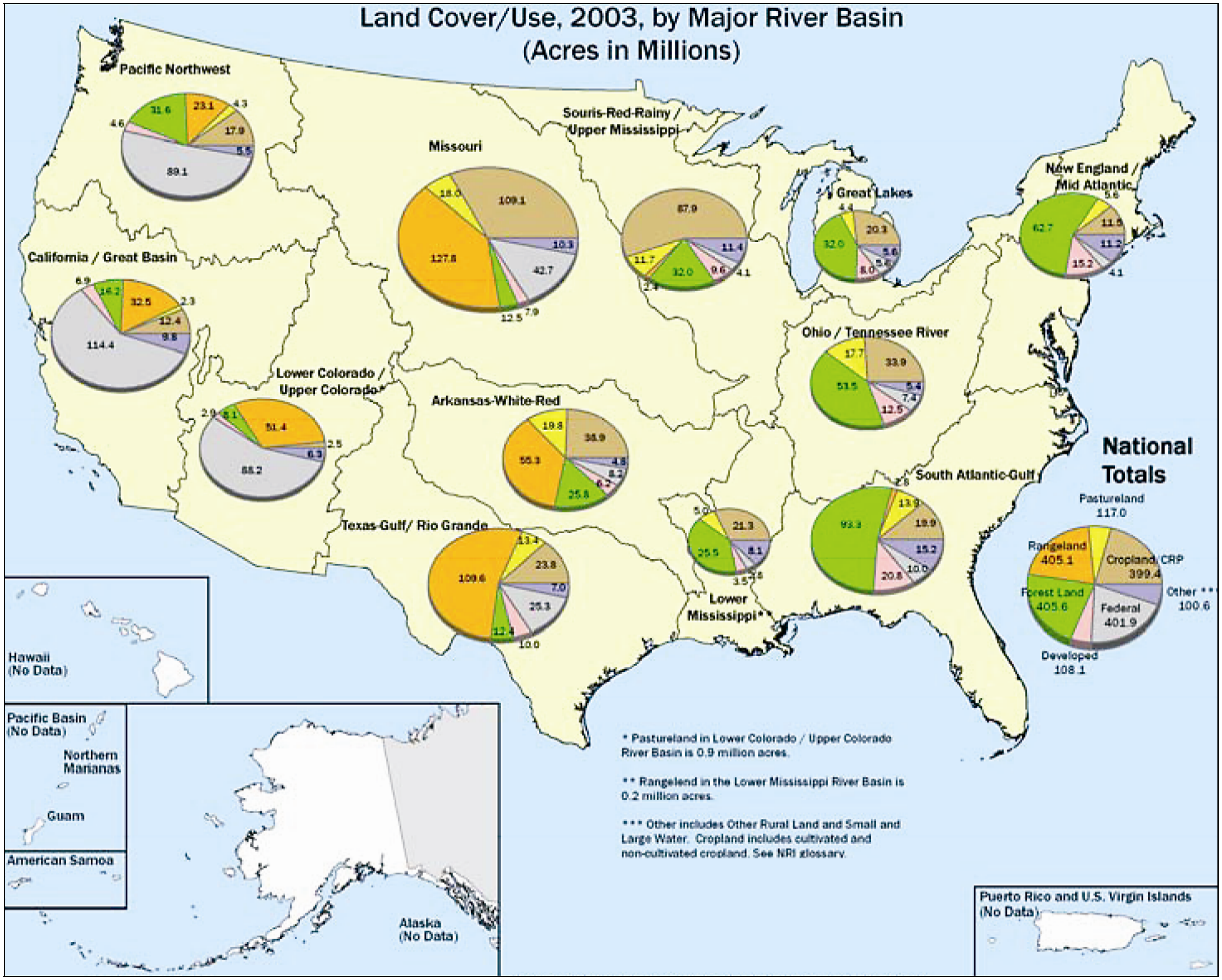


Source: EPA 2007b

FIGURE 3.2.1-1—*Nonattainment Areas of the United States*

3.2.2 Land Use

Land area of the continental United States covers about 1.94 billion acres (785 million hectares [ha]). Allocation of these lands (by major river basin) is illustrated in Figure 3.2.2-1. Cropland, pasture, open range, and forest land comprise the majority of U.S. land resources. The condition of these lands directly or indirectly influences the environment. The ability to meet national objectives for natural resources and environmental quality depends on how these lands are used and conserved (NRCS 2007).



Source: NRCS 2007

FIGURE 3.2.2-1—*Land Cover and Use by Major River Basin for 2003*

Land is required to accommodate the various aspects of a nuclear power plant, such as the reactor facility, cooling systems, waste storage facilities, and other support infrastructure. Additional land is required to mine uranium ore, process the ore into metallic uranium, enrich the uranium, and fabricate the fuel assemblies. Land is also required for disposal of low-level waste (LLW), HLW, hazardous waste, Greater-than-Class-C (GTCC) waste, transuranic waste, and SNF. There is currently no long-term repository available for HLW and SNF (DOE 2008g). In addition, there is currently no disposal capability for GTCC waste (72 FR 40135).

The land area controlled by individual commercial nuclear power plants in the United States ranges from 84 acres (34 ha) to 30,000 acres (12,100 ha); however, the exclusion zones range from 58 acres (23 ha) to 3,192 acres (1,292 ha), with an average exclusion zone area of 742 acres (300 ha). This includes land and facilities to store SNF onsite (NRC 1996). Using the actual size of reactor sites identified in NUREG-1437, the average footprint of existing reactor sites is about 3,000 acres (1,214 ha) (NRC 1996). The land area required for a new reactor would be dependent on factors such as location, reactor design, and cooling water availability.

3.2.3 Water Resources

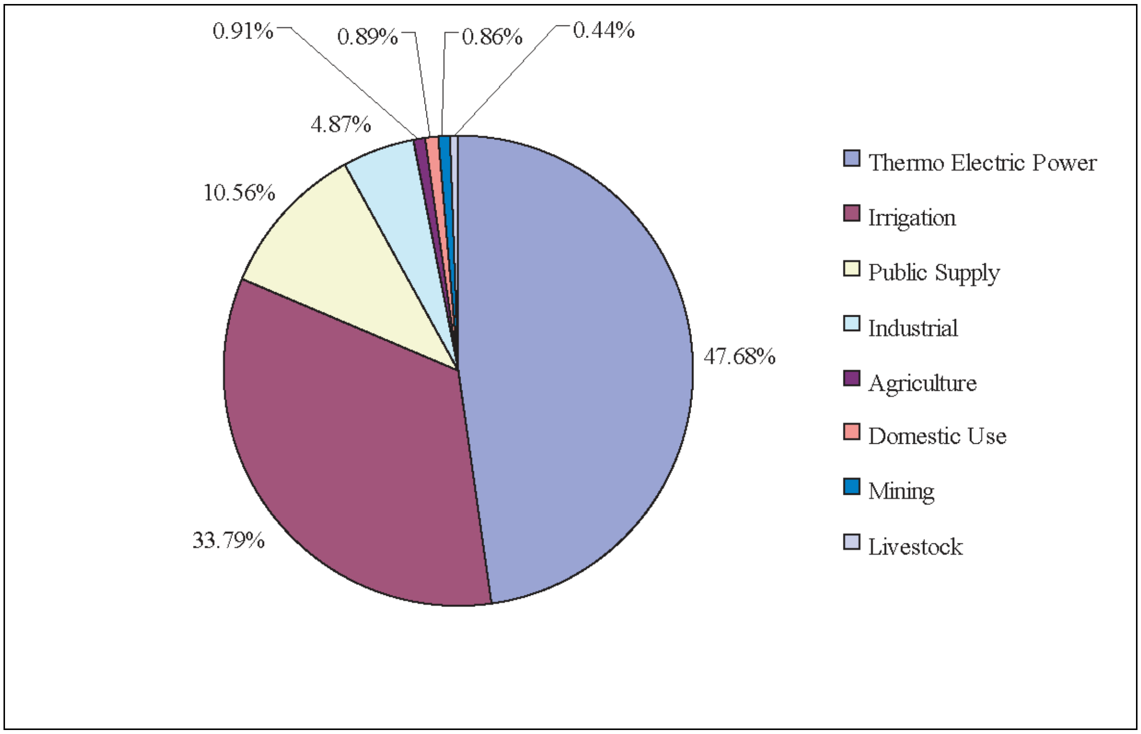
With respect to this discussion on water resources, there are two important terms to define. "Water withdrawal" is the amount of water collected for an activity or process. "Water consumption" is the amount of water that is somehow lost or consumed by the activity or process (e.g., evaporation or leakage), and is therefore not directly returned to the source where it was withdrawn (USGS 2004a). The terms "water use" and "water demand" are used generically to describe either water withdrawal or water consumption.

The U.S. Geological Survey (USGS) estimated that the average amount of water withdrawn daily for all uses in the United States for 2000 was about 405 billion gallons (gal) (1,532 billion liters [L]). Daily withdrawal sources included 83 billion gal (312 billion L) of fresh groundwater, 1.3 billion gal (4.9 billion L) of saline groundwater, 262 billion gal (992 billion L) of fresh surface water, and 58.7 billion gal (221 billion L) of saline surface water (USGS 2004a).

The U.S. Department of Agriculture (USDA) reports water use in the United States by major categories, such as thermoelectric power (i.e., electrical power generated by a thermal conversion process such as a coal-fired boiler or nuclear plant), irrigation, public supply, industrial, agriculture, domestic use, mining, and livestock. Figure 3.2.3-1 illustrates the relative percentage of each category for 2000. Thermoelectric power generation represented the largest share, followed by agriculture and public supply. All other categories represent about 8 percent of total water consumption (USGS 2004a).

Thermoelectric power generation accounted for roughly 192.9 billion gal/day (730 billion L/day), or 48 percent of all withdrawals in 2000. Large amounts of water are needed for cooling. For this reason, thermoelectric power plants are located near an abundant water supply. More than 99 percent of total thermoelectric power withdrawals were from surface waters (USGS 2004a); however, water consumption (evaporative loss to the atmosphere) was only about 2.2 percent of withdrawals.

There are two principal methods of heat rejection at thermoelectric power plants—once through (open-loop) and recirculation (closed-loop). In an open-loop system, the steam is cooled by water that is pumped from an outside source through a condenser and then discharged; usually back into the water body from which it was withdrawn. In a closed-loop system, the steam is cooled in towers and the water that is not lost to evaporation is recycled through the plant with periodic discharges to reduce the concentration of minerals in the circulation water. Open-loop systems have a much higher withdrawal rate than closed-loop systems; however, closed-loop systems lose more water to evaporation, and thus have a higher overall rate of consumption (USGS 2004a).



Source: USGS 2004a

FIGURE 3.2.3-1—*United States Water Consumption by Use Category*

Although open-loop systems have a higher withdrawal rate than closed-loop systems, the USGS report shows that closed-loop power plants accounted for 91 percent of all thermoelectric power withdrawals, and open-loop power systems accounted for 9 percent of the withdrawals. Average water demand (withdrawal and consumption) for each method is listed in Table 3.2.3-1 based on a report from the National Energy Technology Laboratory (NETL). The rates of water withdrawal and consumption required to cool a nuclear power plant are typically higher than for a fossil-fired power plant, because nuclear power plants are designed to operate at lower temperatures and pressures. Operation at a lower temperature and pressure reduces the thermodynamic efficiencies and thus requires more water to reject the heat (NETL 2006b, USGS 2004a).

TABLE 3.2.3-1—*Average Water Demand for a Nuclear Power Generation Plant*

Heat Rejection Method	Withdrawal Rate (gal/kWh)	Consumption Rate (gal/kWh)
Once Through	31.5	0.137
Recirculation	1.10	0.624

Source: NETL 2006b
Note: kWh = kilowatt-hour

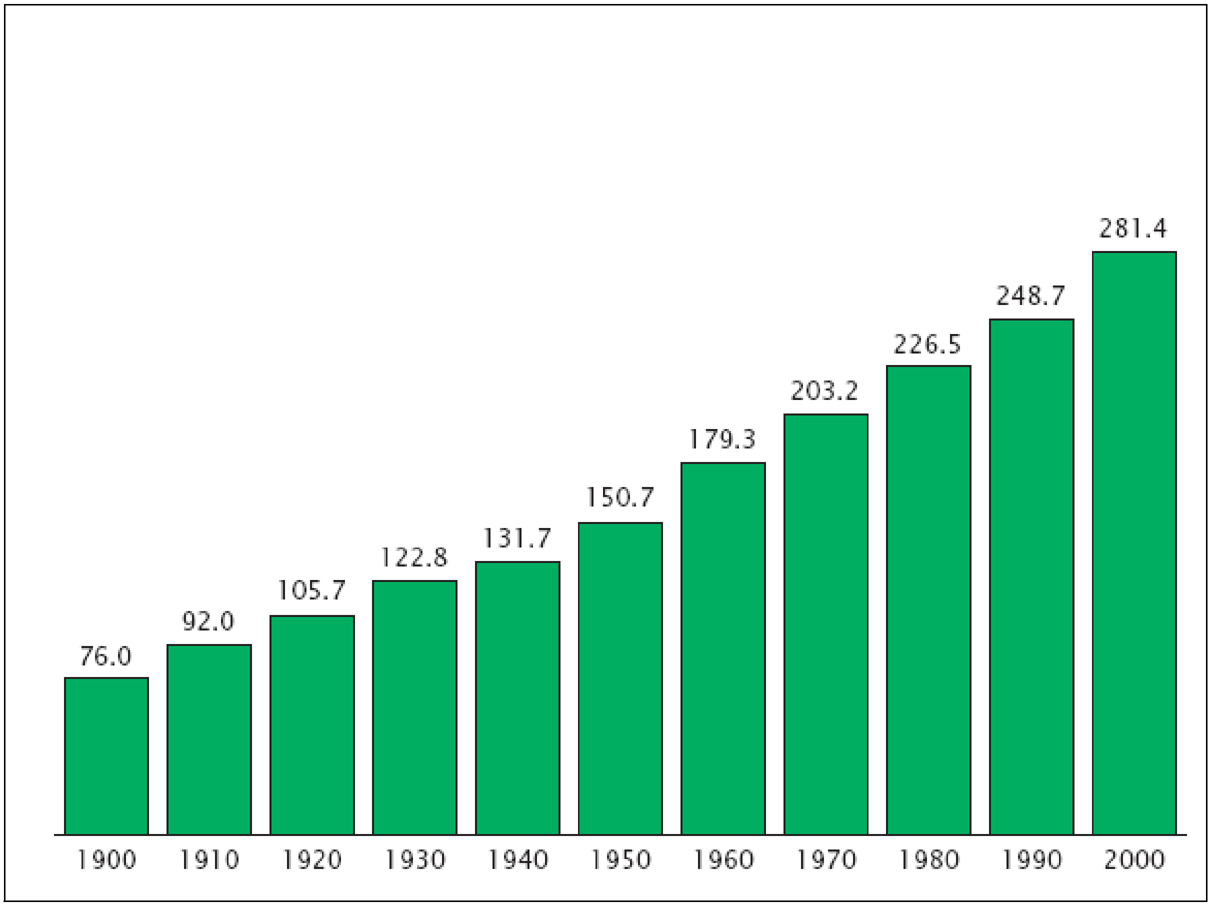
About 44 percent of nuclear power plants use a recirculation system for heat rejection. Daily water withdrawal for U.S. nuclear power generation is around 42.9 billion gal (182.4 billion L). Daily water consumption for uranium mine operations ranges from 0.07 to 0.26 billion gal (0.26 to 0.98 billion L) (NETL 2006b, POA 2006).

3.2.4 Socioeconomics

This section provides an overview of the affected environment for the domestic power generation industry with respect to socioeconomics. It includes a discussion of historical population trends and projected population growth; a description of major industrial activities and employment totals; a description of employment totals associated with power generation and distribution, and the mine activities needed to provide nuclear fuels; a discussion of projected demand growth in the power generation industry; nationwide employment data for the heavy construction industry; and an estimate of the major material requirements for nuclear power plants.

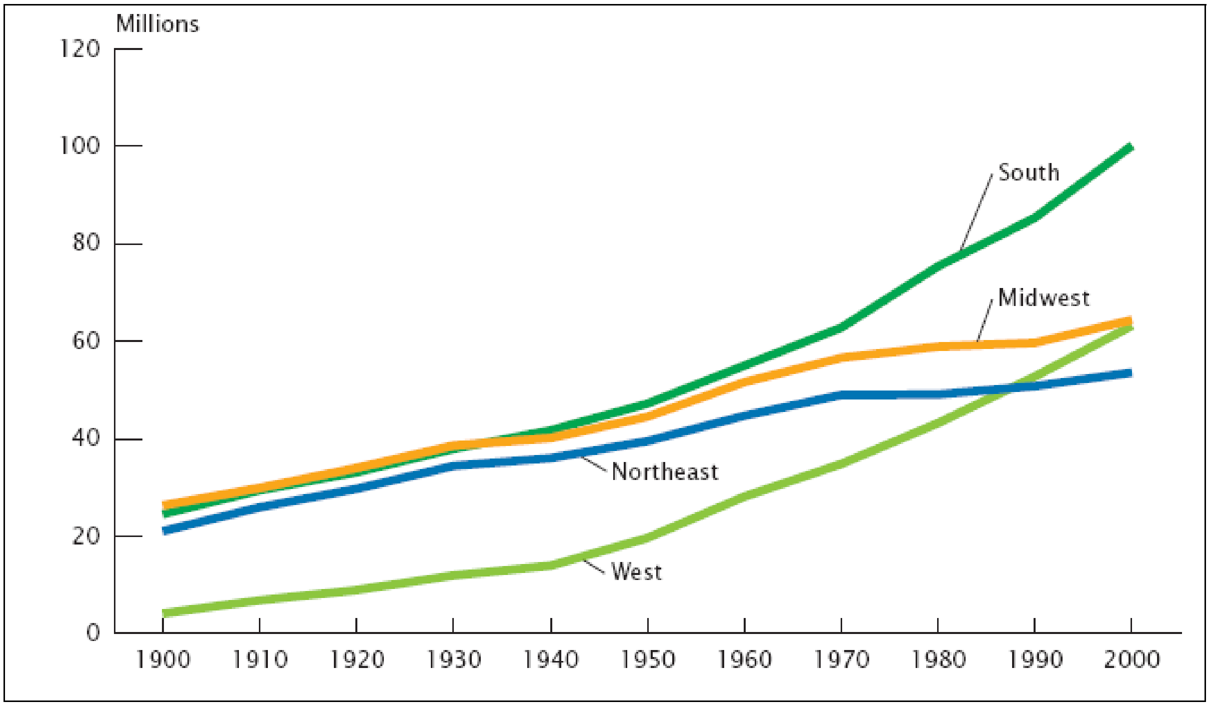
3.2.4.1 *Historical Population Growth*

The current U.S. population is around 303 million, which represents 4.58 percent of the world's population (USDOC 2007a). Between 1900 and 2000, the combined increase of 135 million people in the South and the West represented 66 percent of the U.S. population increase of 205 million people (Figure 3.2.4.1-1). Figure 3.2.4.1-2 shows the population growth by region (USDOC 2002a). Figure 3.2.4.1-3 shows the population density of the United States based on Census 2000 data (USCB 2000b).



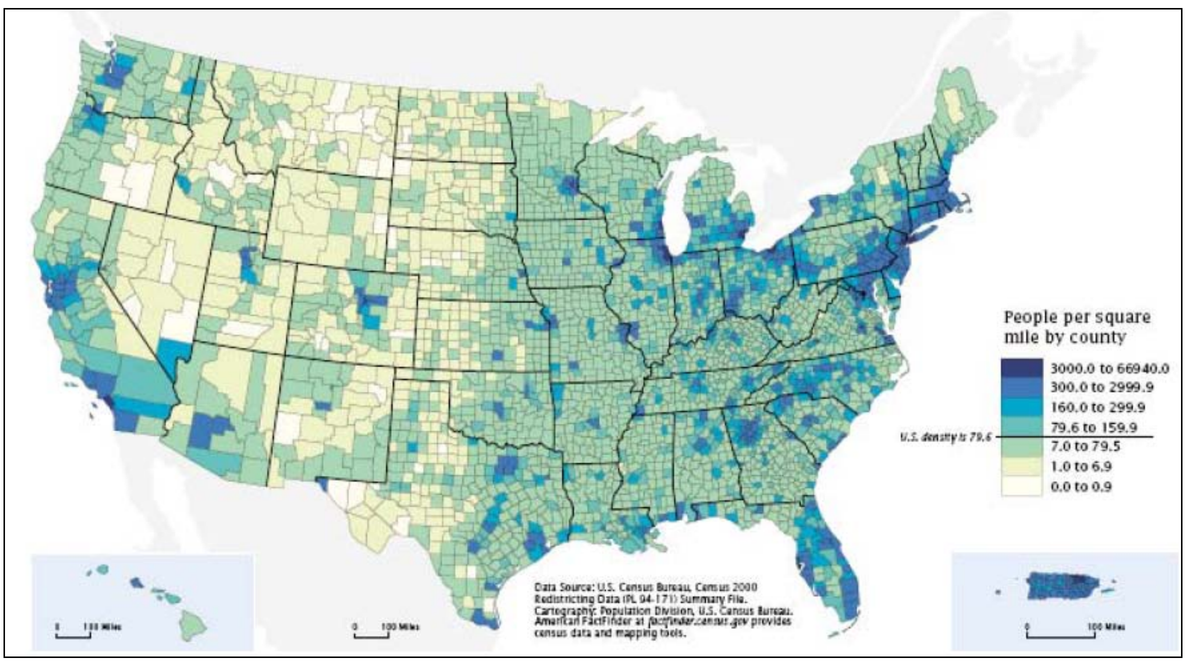
Source: USDOC 2002a

FIGURE 3.2.4.1-1—*United States Population Trend from 1900 to 2000 (Millions)*



Source: USDOC 2002a

FIGURE 3.2.4.1-2—*Population Growth by Region Between 1900 and 2000*



Source: USCB 2000b

FIGURE 3.2.4.1-3—*Population Density of the United States for 2000*

3.2.4.2 *The United States Labor Force*

The Bureau of Labor Statistics (BLS) tracks labor economics and statistics for the Department of Labor. Since 1970, the unemployment rate in the United States has ranged from a low of 4.0 percent in 2000 to a high of 9.7 percent in 1982. The average rate was around 6.2 percent. The recent trend documents a steady decline each year from 6.0 percent in 2003 to 4.6 percent in 2007 (BLS 2008).

3.2.4.3 *Economic Census Data for United States Industry*

Every 5 years the U.S. Census Bureau provides a detailed portrait of the U.S. economy that categorizes economic activity based on the principal activity in which U.S. industry is engaged, consistent with the 2002 North American Industry Classification System (NAICS) that covers 1,179 industry categories (USDOC 2005a).

The most recently available U.S. Economic Census was completed in 2002 and covers 1,070 of the 1,179 industries listed in the 2002 NAICS. The industries included in the 2002 Economic Census are organized into 18 major industrial sectors (Table 3.2.4.3-1). Total employment for these sectors was nearly 109 million; however, this total excludes employment in government and other non-industrial sectors. The total labor force is the number of people age 16 or older who are employed or seek to be employed. The BLS reports that the total labor force in 2002 was about 145 million (BLS 2004).

TABLE 3.2.4.3-1—*Employment by Industrial Sector for 2002*

Industrial Sector	Employment
Educational services	430,164
Mining	477,840
Utilities	663,044
Arts, entertainment, & recreation	1,848,674
Real estate, rental & leasing	1,948,657
Management of companies & enterprises	2,605,292
Other services (except public administration)	3,475,310
Transportation & warehousing	3,650,859
Information	3,736,061
Wholesale trade	5,878,405
Finance & insurance	6,578,817
Construction	7,193,069
Professional, scientific, & technical services	7,243,505
Administrative & support & waste management & remediation service	8,741,854
Accommodation & food services	10,120,951
Retail trade	14,647,675
Manufacturing	14,699,536
Health care & social assistance	15,052,255
TOTAL	**108,991,968**

Source: USDOC 2005b

3.2.4.4 *National Employment for the Electric Power Industry*

An estimated 535,675 people were employed in the electric power generation, transmission, and distribution industry in 2002. This included 122,875 employees for power generation and 412,890 for power transmission, control, and distribution. The number of employees associated with the nuclear power generation industry was around 31,400 based on 62 employees per million megawatt-hours (MWh) and an annual consumption of 507 million MWh (EIA 2007k, USDOC 2005c).

3.2.4.5 *National Employment for the Uranium Mining Industry*

In 2002, an estimated 3,264 people worked directly in the uranium/radium/vanadium mines that support the nuclear power generation industry. This estimate does not include employees who worked in central administrative offices, warehouses, or other establishments that served mining establishments within the same organization (USDOC 2005d).

3.2.4.6 *Projected Growth in Population and Energy Demand*

The U.S. population is projected to increase by 23.2 percent between 2005 and 2030 (USDOC 2004). Over that same time span, total electricity generation is projected to grow by 43.4 percent, and the per capita rate of energy generation is projected to increase by 13.5 percent, from 13.3 MWh per person in 2005 to 15.1 MWh per person in 2030 (EIA 2007a).

3.2.4.7 *Heavy Industrial Construction Industry*

Based on data from the 2002 Economic Census, the construction industry employed nearly 7.2 million workers. As shown in Table 3.2.4.7-1, a total of about 6.65 million workers were involved in heavy industrial and civil construction activities including specialty trade contractors (USDOC 2005e).

TABLE 3.2.4.7-1—*Employment Data for Heavy Industrial and Civil Construction Activities*

Description of Construction Activity	Employment
Nonresidential buildings	791,186
Utility system construction	539,615
Oil and gas pipeline construction	94,323
Power and communication system construction	246,669
Land subdivision	52,607
Highway, street, and bridge construction	410,822
Other heavy construction	140,202
Specialty trade contractors	4,380,432
TOTAL	**6,655,856**

Source: USDOC 2005e

3.2.4.8 *Major Construction Materials*

Principal construction materials for a nuclear power plant include steel and cement. Worldwide demand for these materials has increased rapidly over the past several years. Recent worldwide and domestic consumption data for these commodities are shown in Table 3.2.4.8-1.

TABLE 3.2.4.8-1—*United States and World Consumption of Steel and Cement*

Commodity	World Consumption	U.S. Consumption
Steel	1.2 billion MT[a]	120 million MT[b]
Cement	2.45 billion MT[c]	120 million MT[d]

[a] Penton 2007
[b] IISI 2007
[c] OSC 2006
[d] MSNBC 2007
Note: MT = metric tons

Material requirements for a nuclear power generation plant vary by design and site location, but requirements for a typical 1-gigawatt electric (GWe) nuclear plant include 165,000 tons (150,000 metric tons [MT]) of steel and 937,000 tons (850,000 MT) of cement (CEEDATA 2006).

3.2.5 Radiological Waste Management and Transportation

The major sources of radioactive waste generation in the United States include the nuclear fuel cycle, DOE operations, industry, medical institutions, and research facilities. Nuclear fuel cycle operations and DOE operations represent the majority of radioactive waste generation each year.

As part of the nuclear fuel cycle, radioactive wastes are generated at the uranium mine, the conversion mill, the enrichment plant, the fuel fabrication plant, and the power plant. The bullets below provide a quantitative description of the nuclear fuel cycle material balance for a full year of operation (8,760 hours) for a nominal 1-gigawatt electric (GWe) commercial nuclear power plant (WISE 2006).

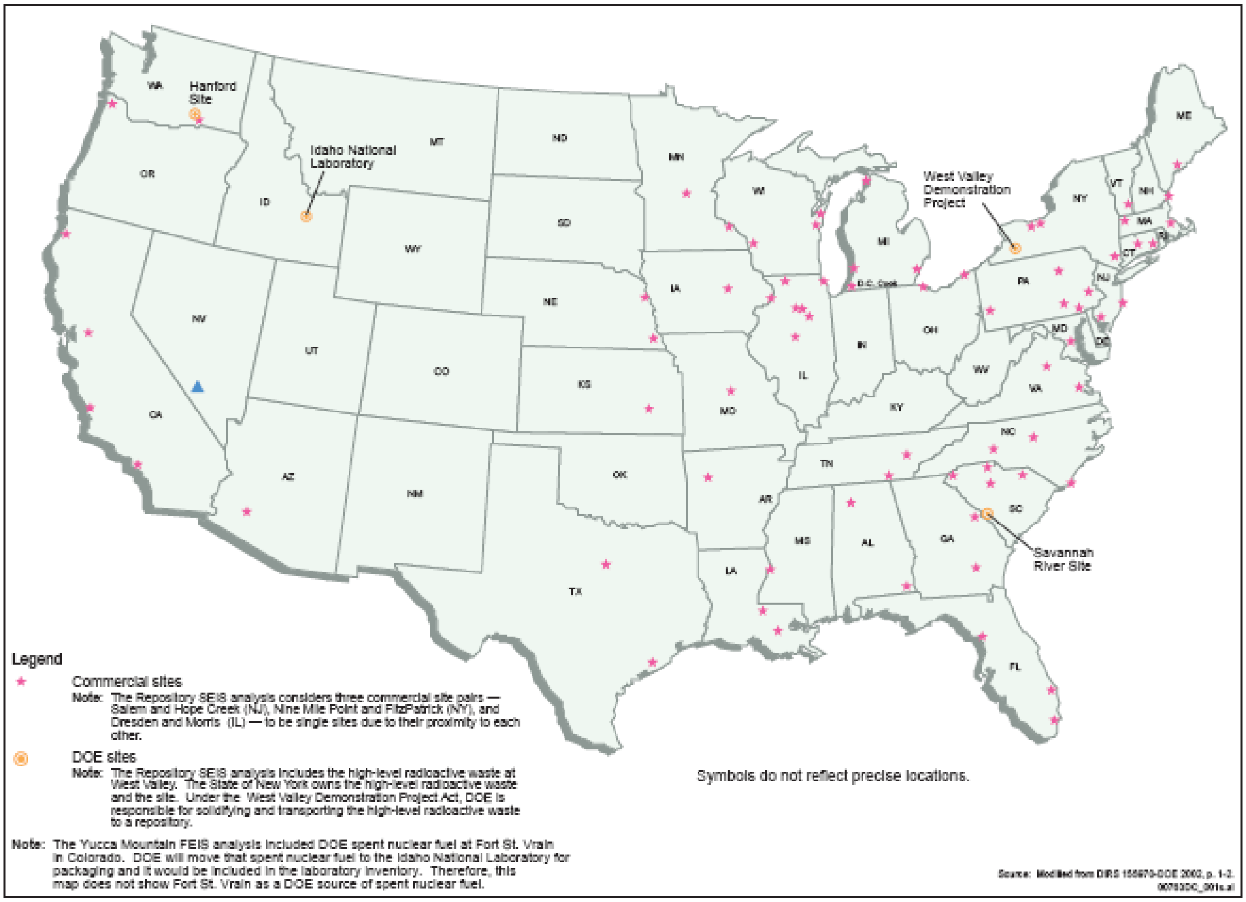
- Uranium mine operations generate 542,000 tons (492,000 MT) of waste rock to produce 108,000 tons (98,400 MT) of uranium ore that contains around 217 tons (197 MT) of uranium metal (WISE 2006).
- Uranium mill operations generate slightly less than 108,000 tons (98,200 MT) of mill tailings to produce 245 tons (222 MT) of uranium oxide in the form of triuranium octaoxide (U_3O_8) (WISE 2006).
- Conversion plant operations generate around 145 tons (131 MT) of solid waste and 47,500 cubic feet (ft^3) (1,340 cubic meters [m^3]) of liquid waste to yield 306 tons (277 MT) of uranium hexafluoride (WISE 2006).
- Enrichment plant operations generate around 268 tons (243 MT) of depleted uranium hexafluoride to produce 38 tons (34.5 MT) of enriched uranium hexafluoride (WISE 2006).

- Fuel fabrication operations generate around 372 ft^3 (10.6 m^3) of solid waste and 6,718 ft^3 (190 m^3) of liquid waste to produce roughly 23.9 tons (21.7 MT) of uranium oxide in the form of UO_2. This quantity of UO_2 contains around 21.1 tons (19.1 MT) of uranium metal (derived from WISE 2006).
- Nuclear power plant operations generate approximately 23.9 tons (21.7 MT) of SNF per GWe-year of production (Wigeland 2008a). Collectively, U.S. nuclear power plants currently generate approximately 2,390 tons (2,170 MT) of SNF each year (EPA 2006a). In addition, a typical LWR generates approximately 740 to 2,790 ft^3 (21 to 79 m^3) of LLW annually (NEI 2007).

In addition to current waste generation volumes, there are significant quantities of legacy HLW that will ultimately require transport to a geologic repository. Figure 3.2.5-1 shows the location of U.S. sites that currently store SNF or HLW destined for geologic disposal (DOE 2008f).

The LLW generated at nuclear power plants is transferred to domestic, permitted, commercial treatment and/or disposal facilities. Treatment facilities process the LLW by various methods to reduce toxicity, reduce volume, and immobilize the waste prior to transferring the waste to a permitted disposal facility. Currently, the United States is served by three commercial disposal facilities which are located in South Carolina, Utah, and Washington (NRC 2007m). The volume and radioactivity of LLW processed varies from year to year based on the types and quantities of waste. In 2005 these facilities collectively disposed of 4 million ft^3 (113,000 m^3) and 530,000 curies (Ci) of LLW (NRC 2007g). Disposal capacity of these facilities is established in licenses with the NRC. Depleted UF_6 is the responsibility of DOE and is currently being stored for further processing at Portsmouth and Paducah Gaseous Diffusion Plants (DOE 2007gg). SNF is currently being stored pending the opening of a geologic repository at Yucca Mountain.

Between 1971 and 2000, more than 2,700 deliveries of SNF traveled over 1.7 million miles (2.7 million kilometers). SNF containers used to transport nuclear waste are the most robust in the transportation industry. Transport containers use several layers of protection and consist of nearly 4 tons (3.6 MT) of structural and shield material for every ton of SNF (DOE 2001g).



Source: DOE 2008f

FIGURE 3.2.5-1—*Sites that Currently Store Spent Nuclear Fuel and High-Level Radioactive Waste Destined for Geologic Disposal*

The environmental impacts associated with the transport and disposal of SNF and HLW in Yucca Mountain geologic repository have been assessed in the Yucca Mountain Supplemental EIS (DOE 2008f).

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